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## RESEARCH ARTICLE

# Salmon trade duration: The application of firm-level trade transaction data from the Norwegian salmon industry

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## Abstract

Seafood products are mainly provided through trade to international markets and Norway is the major international player for the export of salmon products. It is argued that fresh or chilled salmon, which are perishable products and Norway's main seafood export, need stable trade partners to safely and properly reach consumption markets. In this study, the firm-to-firm level trade transactional data for both exporters and importers for the 2005–2018 period was utilized for a trade duration analysis. The Kaplan–Meier survival estimators, Cox proportional hazard model, and frailty model were used to study the stability of trade relations between the partners through survival and hazard models. The study considers the heterogeneous firm trade model along with a theoretical framework. The results show that, on average, the trade duration for the salmon trade between firms is 2.39 years, which is relatively low for a perishable product such as salmon. It shows that the market entry and exit is relatively fast, and that the survival rate between the EU as a major demand market and non-EU

**Abbreviations:** ASEAN, Association of Southeast Asian Nations; COX PH, Cox proportional hazard; EU, European Union; FOB, free on board; GDP, gross domestic product; HFTM, heterogeneous firm trade model; iid, independent and identically distributed; NOK, Norwegian Krone; SD, STANDARD DEVIATION; SEZ, Special Economic Zones; SSB, Statistics Norway; UK, United Kingdom; US, United States.

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countries is not very different. However, core and periphery markets can be defined by considering the survival rate, as major processing hubs in the EU, such as Poland and France as core markets, have higher survival rates compared with other countries that can be considered peripheries. Both extensive and intensive margins were found to reduce the hazard ratio. Different hazard ratios were also found between different types of exporter or ones utilizing different means of transport. We conclude that the trade duration between the partners can be increased if the competition in the market increases, which is probably possible in markets like the United States where other exporters such as Chile are available.

#### KEYWORDS

Cox proportional hazard model, frailty, Kaplan–Meier survival, Norway, salmon, trade duration, trade spells

## 1 | INTRODUCTION

Trade of food and agricultural items is an important element of food systems, and especially if the dependency on food item imports is high (Zurek et al., 2022). Some studies show that higher food and agricultural trade is a sign of a more sustainable food system (e.g., Béné et al., 2020). Trade plays a particularly important role in the international seafood market (Anderson et al., 2018). The seafood consumption per capita has approximately doubled over the last half a century and aquiculture is the main source of supply for this expanded demand, which has approximately tripled in the last 25 years (Naylor et al., 2023). Furthermore, the importance of seafood consumption in supporting food and nutritional security is increasing (Cojocar et al., 2022; Naylor et al., 2023). Rising incomes, urbanization, improvements in postharvest practices, and changes in dietary trends are projected to increase seafood consumption (FAO, 2022). The global production of aquatic animals was estimated at 178 million tonnes in 2020, a slight decrease from the all-time record of 179 million tonnes in 2018 (FAO, 2022). According to the FAO (2020), in 2018, 67 million tonnes of fish (live weight equivalent) were traded internationally, which accounts for almost 38% of all fish caught or farmed worldwide. The trade data shows that 221 states and territories reported some fish trading activity globally. The total export value of fish products in 2018 reached 164 billion United States dollar (USD), which was approximately 11% of the value of agricultural product exports (excluding forest products). Three separate but interconnected sectors contribute to the global seafood supply, which are commercial capture or wild-caught fisheries, recreational or subsistence fisheries, and aquiculture (Cojocar et al., 2022). Norway is the second top exporter of seafood internationally and Norway has an important share in aquaculture as the world's largest producer and exporter of farmed Atlantic salmon (FAO, 2022). There is a consensus among a group of scholars that the trade of aquaculture (including farmed salmon) as the main driver of tremendous growth of seafood production and trade may have a different pattern compared with traditional wild fish products due to a higher degree of control in production processes, increasing efficiency and the targeting of more valuable products (Straume et al., 2020). The gravity models are standard models that are developed to analyze the trade intensity and trade flow. Trade duration is another emerging area for studying trade stability and according to Straume (2017), given the general literature on the subject,

the development of stable trade relations is an important success criterion for exporters of aquaculture products. A concern here, however, is the relation between the increasing growth in trade and the length of the trade duration, as a termination in trade between partners means no trade growth (Hess & Persson, 2012). Trade stability or the survival of a trade relation between an exporter and importer is a necessary requirement for deepening trade and export growth that at least covers the cost of establishing a trade link (Besedeš & Prusa, 2011). In this context, trade duration analysis is an approach for exploring the length of trade relationships without interruptions and factors affecting the length of those relationships. A situation of longer trade between partners is a sign of higher vertical coordination and lower transaction costs (Ketokivi & Mahoney, 2020). Observing the available trade relations shows that a large share of trade relations are short lived and, if a trade relationship survives in an export market over a period of time, the possibility of trade failure decreases tremendously (Straume, 2017).

There is no clear theoretical framework available for the direct analyses of the duration of trade relationships (Engemann et al., 2022; Fugazza & Molina, 2016). However, the heterogeneous firm trade model (HFTM), introduced by Melitz (2003), can be used to explain trade duration. In this theory, firm differences in productivity and fixed entry costs for each export market are key for explaining trade. As the expected profits through trade may not cover the export costs, exporting firms may revise their expectations once they enter into a new market or during their trade activities (Besedeš & Prusa, 2011; Nguyen, 2012). Furthermore, an importer's decision to continue its trade relationship with their suppliers depends on an exporter's ability to fulfill the expectations (Peterson et al., 2018). Trade duration models allow us to consider time as an element in the trade relationship and study the disruption or interruption of trade. In the firm-to-firm trade relation, this interruption can have different reasons, which has partially been explained before. Duration, survival, hazard, or persistence, which can be used interchangeably, are all different terms used for the same type of research areas.

In spite of all argumentations on the importance of trade stability, the short-lived trade relation has been acknowledged in some trade duration studies and has even been named "trade duration puzzles" by some scholars (e.g., Gullstrand & Persson, 2015; Zongo et al., 2022). Other scholars argue that the stability of trade flow is of higher importance for food items and especially perishable foods (Peterson et al., 2018). The duration of salmon exports, which is mainly traded fresh or chilled from Norway, is the issue that's explored in this paper. Fresh salmon is a perishable product and a stable trade relationship should thus be important for its trade (Straume, 2017). However, there are some observations that assert that a different pattern can be found for the salmon trade. For instance, in their study, Asche et al. (2021) conclude that the gravity model of the salmon trade showed different pattern in comparison to storable food commodities. They argue that the distance doesn't have the same magnitude of effect and that economies of scale in transport is not utilized for salmon. These findings have further motivated this analysis of the duration of the salmon trade. A review of the available literature on food trade duration for the seafood industry shows that they have not investigated the firm-to-firm trade duration and the factors that affect these sorts of trade relations. For instance, Asche et al. (2021), Gaasland et al. (2020), and Straume et al. (2020) have used gravity models to study the salmon and seafood exports from Norway by employing firm-to-country trade transaction data. In two studies, Straume (2017) and Asche et al. (2018) have analyzed the trade duration of salmon and cod from Norway using firm-to-country trade transaction data. Finally, Wang et al. (2019) have studied the country-to-country seafood trade duration from the Association of Southeast Asian Nations (ASEAN) region. Utilizing firm-to-firm trade data provides an opportunity to study HFTM from firm-level microdata on both the exporter and importer sides. As much as the custom data allowed us, we tried to test different aspects of trade heterogeneity characteristics. To our knowledge, this is the first study that has considered the HFTM theory and used the firm-level transaction data on both sides of trading to study the seafood trade. Therefore, in this study, we apply the survival/hazard approach to analyze the trade duration pattern. For this analysis, we have used firm-level transaction data on salmon between exporters and importers for the 2005–2018 period. Additionally, by considering the heterogeneous aspects of trade (e.g., the type of exporters or means of transport), as far as anonymity of data allowed for in this data set, we have tested the effect of the income level of importers on trade duration, as income growth increases seafood consumption (as explained above). The results show that the salmon

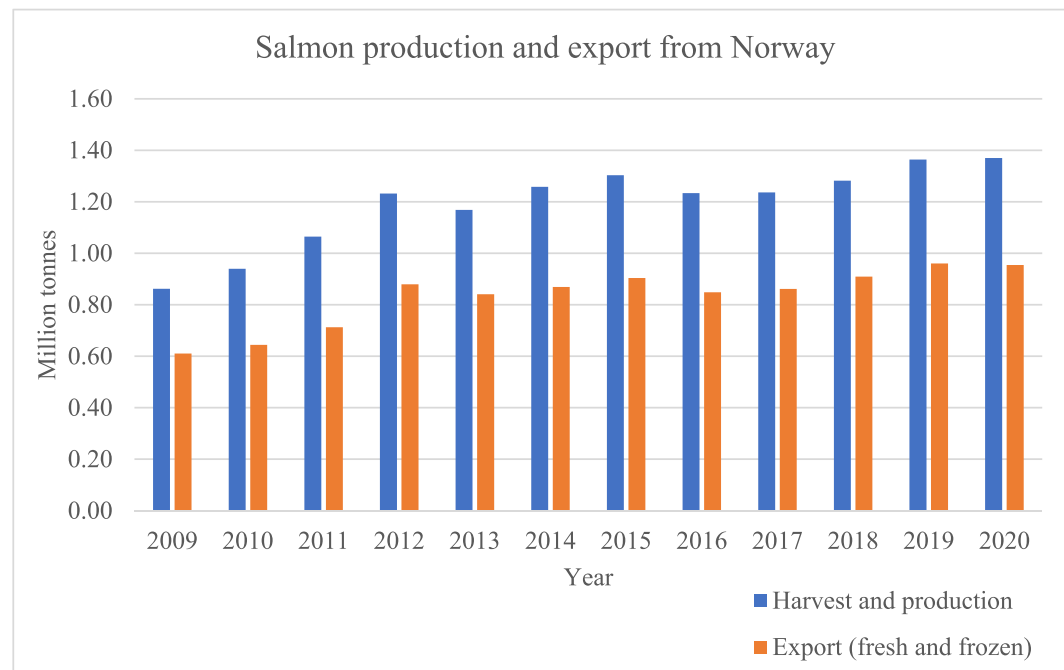
trade duration is relatively short lived (2.39 years on average) and the stability of trade between different importing markets is not huge considering major and minor markets or different continents. However, we also recognize a higher survival rate for trade with major secondary processing hubs such as France and Poland. Additionally, differing characteristics of exporting firms affect the stability of trade with importers. The results of this study can be useful for three different areas: First, it gives foresight to exporting firms that they should not expect longer or shorter trade relations between the major or minor markets of the salmon trade. Furthermore, it provides a measure for importers for the length of stability of salmon exports. Finally, this approach can be generalized to all fresh and perishable products that are provided by limited exporters to international markets.

The next section presents an overview of the Norwegian salmon supply chain and trade. Later on, a summary on the available literature on food trade duration will be provided. The methodology and data are presented in the subsequent sections followed by the results, discussion, and conclusion.

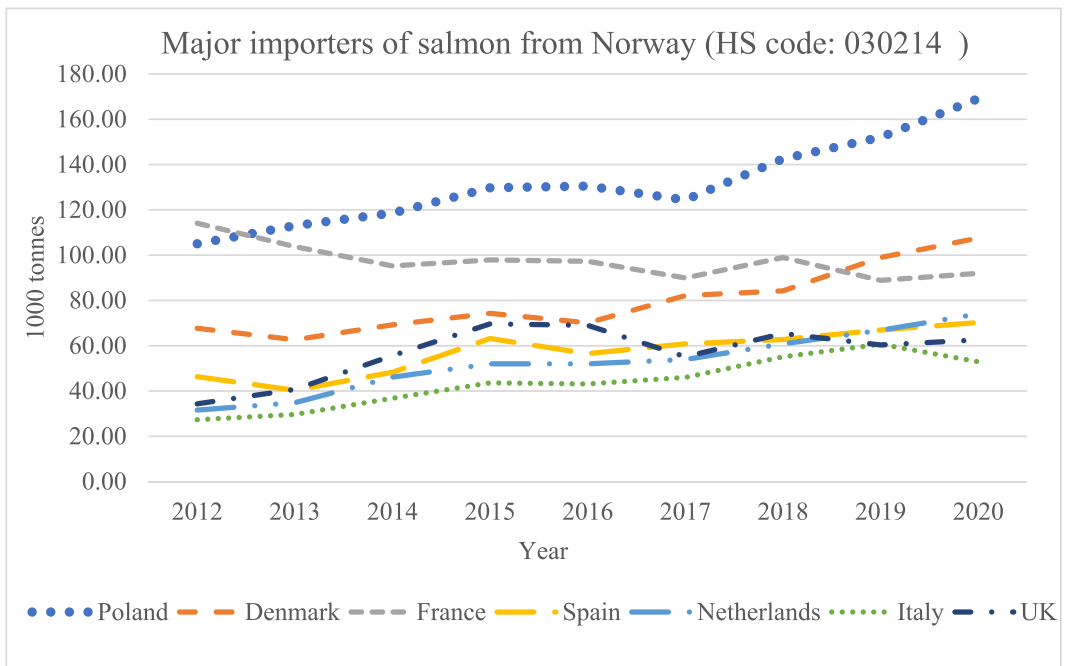
## 2 | THE ROLE OF NORWAY IN THE INTERNATIONAL SALMON TRADE

Norway is the main producer of salmon in the world. In 2020, of the 2.7 million tonnes of Atlantic salmon harvested worldwide, 1.37 million tonnes were from Norway (Kontali, 2021). The main share of salmon production in Norway is for exports (Figure 1).

Chile is the next major exporter of salmon products. The natural conditions of water temperature play a major role in having a limited number of salmon producers globally. Salmon is the number one species traded on the European market for fish and seafood products in terms of value and the third fish species consumed (after tuna and cod) (Olafsdottir et al., 2019). Fresh or chilled salmon comprise the bulk of these salmon exports (TradeMap, 2022), and the main bulk of Norwegian exports go to European Union (EU) countries such as Poland, France, Denmark, Spain, Netherlands, Italy and the United Kingdom (UK) (Figure 2).



**FIGURE 1** Salmon production and export, 2009–2019. Source: Kontali (2021) and TradeMap (2022)20212022



**FIGURE 2** Main salmon importers from Norway. Source: TradeMap (2022)2022

The analysis of the Norwegian salmon supply chain shows that fresh head-on gutted (HOG) salmon is the main form of exports to the industrial customers for further processing into products such as fillets, portions, smoked salmon, or ready-made foods (Olafsdottir et al., 2019). This fact makes the governance of the salmon supply chain an important subject of attention when it comes to understanding its trade patterns. For instance, from the top four major salmon producers in Norway (MOWI, Lerøy Seafood Group ASA, Cermaq Norway, and SalMar Farming AS), MOWI and Cermaq Norway can be categorized as global firms with additional production facilities in Chile, the UK, and North America (Olafsdottir et al., 2019). According to Hersoug (2021), 70% of salmon production in 2019 was conducted by the 10 top firms, which shows a level of concentration in this industry. On the export side, France is the largest consumption market for salmon in the EU. A large part of secondary (value-added) processing of Norwegian salmon takes place in France, Poland, and Denmark. The production and export of salmon from Norway is on the rise (Olafsdottir et al., 2019). Another interesting aspect of the Norwegian salmon supply chain is the relatively low level of market imperfection at the primary stages of the salmon supply chain, which was found by Jaghdani et al. (2020). In spite of having a natural monopoly on salmon production and exports, higher market power was expected among the Norwegian producers and exporters. This could be due to license control measures imposed by the government regarding production levels (Hersoug, 2021). In the next section, the conceptual framework for trade duration and available studies on food and seafood trade duration are presented.

### 3 | TRADE DURATION OF AGRICULTURAL AND SEAFOOD PRODUCTS

Trade duration models are an evolving field of trade analysis and since the HFTM was introduced by Melitz (2003), trade duration models have received a new ground for studying the extensive and intensive margins of trade by considering the firms' heterogeneity. In this regard, Besedeš and Prusa (2011) identify the establishment of new trade relationships (extensive margin) and the deepening of established trade relationships (intensive margin) as key

determinants of export duration and export growth. Correspondingly, Lejour (2015) finds new trade relationships for Dutch firms for existing products to be more stable than new trade relationships with new products. Many studies (e.g., Besedeš & Prusa, 2011) show that an intensive margin is more important for trade duration and growth, while few studies (e.g., Hinz et al., 2019) trace export growth back to the extensive margin.

As a stable trade relation can reduce the risk of disruption for perishable food items especially, more and more studies can be found on the different aspects of the trade duration for food items to assess the effect of trade policies and barriers to the duration of trade relationships. For instance, Luo and Bano (2020) investigate New Zealand's dairy exports; Peterson et al. (2018) study US imports of certain fruits and vegetables; and Engemann et al. (2022) analyze the trade of agro-food products between the EU-28 and sub-Saharan African countries. The results of Peterson et al. (2018) suggest that long-lived trade relationships are of primary importance for the trade of highly perishable food products. They also find that sanitary and phytosanitary measures increase the hazard rate of trade partnerships, particularly in the first years of policy implementation. Similarly, Luo and Bano (2020) trace back the decreasing hazard rate of dairy export relationships in New Zealand to technical barriers to trade implemented by importing countries. Finally, Engemann et al. (2022) find that institutional quality plays an important role in the trade duration of agro-food products. Disaggregated customs data on individual trade transactions makes it possible to analyze trade stability and the duration of trade relationships at the firm level. For instance, Gullstrand and Persson (2015) looked at Swedish firms and find the trade duration of food items to be higher in core markets (firms' primary export destinations) than in peripheral markets (firms' minor export markets). Imamverdiyev et al. (2015) have conducted the only study that examines the trade duration of Kazakh wheat exports using aggregated country-level data. They conclude that trade costs, local production factors, price competitiveness, and experience explain the short duration of Kazakhstan's wheat exports.

As one of the traded perishable goods, seafood products have been of interest for trade duration studies as stable trade relations are of higher importance. As has been mentioned before, there have been some specific studies on the duration of seafood exports. For instance, Straume (2017) studied the fresh-farmed salmon exports from Norway, considering firm-level data from exporters to different countries. He finds that trade duration is remarkably short (4 years on average). Market uncertainty in the form of transportation costs and exports to countries in the EU are associated with a larger probability for failure. Factors that are associated with a reduced risk of exiting the market are the size of the initial shipment between the trading partners, continuing large shipments, and the size of the exporting firm. Wang et al. (2019) studied seafood exports from the ASEAN. They conclude that if a trade activity can survive for 3 years, the easier it is for it to survive longer. Additionally, larger seafood outputs from the ASEAN region decreases the probability of trade failures. Asche et al. (2018) have studied the trade duration of Norwegian cod exports using firm-level data from exporters to different countries. They find that the duration of most trade relations is very short. They conclude that this supply chain stayed very traditional. Finally, Yang et al. (2020) studied shrimp exports from China at the firm level, discovering that most of the trade relationships in the Chinese exports of shrimp were short-lived and influenced by the market as well as product characteristics. The results indicate that it was crucial to account for firm-specific characteristics and that large firms have more stable trade relationships. It is also worthwhile to note that the firms located within Special Economic Zones (SEZs) have a shorter trade duration than those outside of SEZs, indicating these firms' opportunistic market behavior.

The studies mentioned above, and specifically, those focused on the seafood industry, have not investigated the firm-to-firm trade duration and the factors that affect these sorts of relations. Using firm-to-firm trade transaction data contributes to the available literature in two ways: First, it can help to estimate a practical measure for survival or hazard of trade relation, which can be important for decision-making for both the exporters and importers of seafood products. Additionally, it helps to test the HFTM directly with firm data, which is our main contribution with this study. In the next section, the methodology and data that have been used for this analysis are presented.

## 4 | METHODOLOGY

In this study, we've applied four different models of duration analysis to understand the trade persistency. Duration analysis, which utilizes time-to-event data or survival data, depends heavily on the type of the selected models. In this type of data, survival time is defined as the time it takes for an event to occur. Thus, there are three basic elements that must be well-defined for time-to-event analysis: (1) a time origin, (2) a scale for measuring time, and (3) an event (Broström, 2022; Tutz & Schmid, 2016). In the context of trade duration, we define an event as a failure of trade relation after one or several successive years of trade between two firms in two different countries (adapted from Besedes & Prusa, 2006a, 2006b). In this study, trade relation is defined as salmon trade between a Norwegian exporting firm and a foreign importing firm. Furthermore, a spell of trade is defined as the period of time with uninterrupted imports of salmon from a specific exporter in Norway by a specific importer in a destination country (Peterson et al., 2018). There are a wide variety of survival/hazard functions. The models selected are a nonparametric Kaplan–Meier survival model, semiparametric nonlinear survival estimate Cox proportional hazard (COX PH) models, Cox proportional hazard models with frailty (random effect), and weighted Cox regression, which are explained more fully below. References such as Davidson and MacKinnon (2004), Moore (2016), Tutz and Schmid (2016), Broström (2022), and Balan and Putter (2020) were utilized for presenting the statistical models in this part.

### 4.1 | Duration models (survival and hazard)

As mentioned above, the object of interest in this study is the survival/hazard of exports of selected commodities (salmon in this case) by firm  $i$  from Norway to another firm  $j$  in country  $k$ . In survival analysis, we use  $T_{ijk}$  as a nonnegative random variable representing the failure time (or the time until trade cutting occurs) of an individual from the homogeneous population. Instead of defining the statistical model for the response  $T$  in terms of the expected failure time, it is advantageous to define the survival function,  $S(t)$ :

$$S(t) = \text{Prob}\{T_{ijk} > t\} = 1 - F(t), \quad (1)$$

where  $F(t)$  is the cumulative distribution function. If the event is trade failure,  $S(t)$  is the probability that trade failure occurs after time  $t$ , that is, the probability that the subject of trade relation will survive at least until time  $t$ .  $S(t)$  is a nonnegative right-continuous function of  $t$  with  $S(0) = 1$  meaning all subjects survive at least to time zero. The survival function must be nonincreasing as  $t$  increases.

Another important function is the hazard function,  $h(t)$ , also called the force of mortality, or instantaneous event (death, failure) rate. The hazard at time  $t$  is related to the probability that the event of trade failure will occur in a small interval around  $t$ , given that the event has not occurred before time  $t$ . It is defined as:

$$h(t) = \lim_{\delta \rightarrow 0} \frac{\text{Prob}\{t \leq T_{ijk} < t + \delta | T_{ijk} \geq t\}}{\delta} = \frac{F(t + \delta) - F(t)}{\delta S(t)} = \frac{f(t)}{S(t)}. \quad (2)$$

The hazard function or hazard rate is an estimate of the rate at which spells fail after a duration of a period, given that they last up until time  $t$ . By defining the basic statistical model, the empirical model will be presented. The object of interest in this study is the hazard of exports of salmon to selected countries all over the world.

#### 4.1.1 | Kaplan–Meier survival

The Kaplan–Meier estimator is a nonparametric estimate of a survival function  $S(t)$  as defined above:



$$\hat{S}(\hat{T}_m) = \prod_{t=1}^m \frac{n_t - d_t}{n_t}, \quad (3)$$

where  $n_t$  is the number of objects (trade relations in this case) at risk at time  $t$ , and  $d_t$  is number of failures of trade at time  $t$ . This estimator is a standard robust measure in survival analysis. However, it does not say anything about the relation between the survival rate and potential covariates.

#### 4.1.2 | Cox proportional hazard model

To measure the effects of the influencing factors on the failure/hazard rate, the semiparametric Cox proportional hazard rate model (COX PH) is commonly used:

$$h(t; \mathbf{X}, \boldsymbol{\beta}) = h_0(t)e^{\mathbf{X}\boldsymbol{\beta}}, \quad (4)$$

where  $h(t; \mathbf{X}, \boldsymbol{\beta})$  is hazard rate at time  $t$ . Two parts can be defined for this model;  $h_0(t)$  is the baseline hazard rate which captures hazard changes as a function of time, and exponential part ( $e^{\mathbf{X}\boldsymbol{\beta}}$ ), which is relative hazard ratio that  $\mathbf{X}$ , is the vector of covariates, and  $\boldsymbol{\beta}$  is the time invariant vector of coefficients of the covariates. The COX PH model assumes a proportional hazard rate, which implies that the ratio of the hazard rate of the two factors is the same at all time points. The time effect on the hazard rate is reflected in the baseline hazard. The COX PH model is the main choice of duration models as it is a reasonable compromise between the Kaplan–Meier estimator and the possible excessively structured parametric models. Cox's partial likelihood estimator provides a method of estimating the parameters without requiring the estimation of the baseline hazard (Greene, 2020).

#### 4.1.3 | Frailty model

In the trade duration models, the covariates account for observed heterogeneity. There are unaccounted parts which are termed unobserved heterogeneity of clusters consisting of countries or firms that cannot be simply captured. If this is the case, then the estimated hazard for a specific set of covariates does not have an individual interpretation. The effect of the unobserved heterogeneity on time-to-event data is referred to as frailty (Balan & Putter, 2020). It could also be the case that subjects in the same cluster are more alike in their survival time compared with subjects in other clusters (Moore, 2016). This problem can be solved by including the multiplicative frailty term  $\mathbf{Z}$  in the hazard model. By expanding Equation (4) as follows:

$$h(t; \mathbf{X}, \boldsymbol{\beta}, \mathbf{Z}) = h_0(t)\mathbf{Z}e^{\mathbf{X}\boldsymbol{\beta}}. \quad (5)$$

We have unobserved heterogeneity  $\mathbf{Z}$  included in Equation (5) and it is assumed to be drawn independently for each individual (or clusters/strata). Hazard rates for “random survivors” are not proportional but converge if the frailty distribution has finite variance. Shared frailty is an empirical approach for estimating the model. Frailty models best work when there is a natural grouping of data. In this data structure, observations from the same group are dependent, while two individual survival times from different groups can be regarded as independent (Balan & Putter, 2020; Broström, 2022). In this regard, the vector of  $\mathbf{Z}$  is the independent and identically distributed (*iid*) strata (could be clusters or individuals) with lognormal distribution. By considering  $\mathbf{U} = \log(\mathbf{Z})$ , we get the following equation:

$$h(t; \mathbf{X}, \boldsymbol{\beta}, \mathbf{U}) = h_0(t)e^{\mathbf{X}\boldsymbol{\beta} + \mathbf{U}\mathbf{U}} \sim G(0, \sigma^2). \quad (6)$$

Complementary to Equation (4),  $\mathbf{U}$  is *iid* and modeled as the Gaussian distribution with mean zero and unknown variance  $\sigma^2$  (Broström, 2022; O'Quigley, 2021; Therneau & Clinic, 2022).

#### 4.1.4 | Test of proportionality and weighted COX PH model

As was explained in subsection 3.1.2, the COX PH model has a restricted assumption of proportionality of covariates. This can be tested by weighted residuals (Grambsch & Therneau, 1994) that we have conducted. To have a more robust model in the case of the violation of proportionality assumption, the weighted Cox regression has been applied (Dunkler et al., 2018; Schemper et al., 2009). R statistical software was used for this analysis and packages “survival,” “coxme,” “coxphw,” and “ggplot2” were employed.

## 5 | DATA DESCRIPTION

### 5.1 | Trade data

The dataset used in this study consists of import and export transactions of all fish products to and from Norway for the 2005–2018 period, which was acquired from Statistics Norway (SSB). The total number of export trade transactions are 3,474,726, covering all export transactions of fish products out of Norway. Only the transactions for the salmon trade were considered for this study, thereby removing around 24% of the dataset. Thus, the final data set consists of 2,630,008 salmon trade export transactions. The commodity list in the data set follows the nomenclature of the Norwegian Customs Tariff, which, since 1988, has been based on the combined tariff/statistical nomenclature, the Harmonized System (HS) and United Nations (UN) standard international trade classification (SITC-Rev. 4).<sup>1</sup> Comparing the trade patterns in the beginning of the period to the end of the period, some differences in the trade patterns appear. In 2018 Norwegian salmon exports were directed toward 99 countries and the total number of trade transactions was 183,967. In 2005, the total number of trade transactions was less than 144,954 and exported to 90 different countries. In this data set, a large drop in the number of trade transactions toward Russia is recognizable. From being one of the core markets in 2005, there were only a few reported export transactions in 2018. On the other hand, the US and Canada, as well as more countries in Asia, have become more important markets for Norwegian salmon. The data set is arranged considering the right censoring concepts in trade data.

### 5.2 | Explanatory variables and the identification process

The data set shows that three continents are important for the Norwegian market today: Europe, America, and Asia. Traveling distance data between all countries was collected from the CEPII<sup>2</sup> Geodist database (Mayer & Zignago, 2011). To provide the right database, we had the challenge of a complicated coding system for the importer, as SSB has anonymized the identity of exporters and importers. This problem was solved by creating a unified code for the importers of salmon from Norway in the SSB database. The data were aggregated annually at the firm level and 33,326 observations were finally acquired for analysis. Having the trade database ready, the dependent variable was made as a time-to-event variable. The covariates were selected based on two factors: (a) the available characteristics of the trade between two partners that reflect the heterogeneous aspects of trade and especially exporting firms regarding HFTM and (b) the available market and macro indicators that are common in trade duration analysis that potentially can affect the hazard ratio. The variables that are presented here are those who are significant or could not be eliminated from models considering the model selection criteria. For instance, an

<sup>1</sup>The commodity codes from Statistics Norway: <https://www.ssb.no/294954/statistisk-varefortegnelse-for-utenrikshandelen-2017>.

<sup>2</sup>CEPII refers to the French Centre for Research and Expertise on the World Economy or “Le Centre d’études prospectives et d’informations internationales”.

**TABLE 1** Descriptive statistics, explanatory variables at firm-to-firm and firm-to-country levels, 2005–2018.

	Number of dummies = 1	Mean	SD	Min	Max
GDP per capita (log of USD)	–	10.00	1.04	5.37	11.621
Exporter, primary producer (dummy)	4397	0.13	0.34	0	1
Exporter, wholesaler (dummy)	22,145	0.67	0.47	0	1
Exporter, processing (dummy)	6694	0.20	0.40	0	1
EU dummy (1 EU, 0 non-EU)	16,702	0.5	0.5	0	1
Air transport (dummy)	7958	0.24	0.43	0	1
Rail transport (dummy)	1	0.00	0.01	0	1
Road transport (dummy)	19,032	0.57	0.49	0	1
Ship transport (dummy)	4403	0.13	0.34	0	1
Mix transport (dummy)	1842	0.06	0.23	0	1
Firstyear_2005 (dummy)	3984	0.12	0.32	0	1
Ratio of number of transactions in last year to 1st year	–	1.91	11.92	0.001	1327
Trade weight in last year (tonnes)	–	89.79	503.44	0.001	61,067.49
FOB price per unit (NOK/KG) <sup>a</sup>	–	51.51	52.26	35.13	6879
SD of salmon price in Norway	–	4.47	1.77	1.49	6.974

Source: SSB, IMF, ERS.

<sup>a</sup>Norwegian Krone per kilogram (NOK/KG).

exporting's firm number of employees; the initial level of exports at the beginning of a spell; the indicator of multiple spells; regional fixed effects; year fixed effects and other available variables in customs data related to trade at micro-level characteristics were not significant and were thus not considered. The same issue has happened with macro variables for the importing countries such as distance, exchange rate, continent fixed effects, and so forth. The variables, which are presented in Table 1, are those that were significant or cannot be eliminated from the models due to the model selection process. The annual unit free on board (FOB) export value of trade between partners, the standard deviation (SD) of salmon prices (fresh or chilled) in Norway and the income level of the importing countries are three additional variables that are presented. The export value of trade was extracted from the transactions data while salmon prices in Norway were acquired from the SSB and International Monetary Fund (IMF). The country-level data such as gross domestic product (GDP) per capita and exchange rates (constant value) were acquired from the Economic Research Service (ERS)<sup>3</sup> website and the World Bank (WB).<sup>4</sup>

We expected that a higher export value would encourage the exporters and discourage the importers of longer trade durations. Additionally, we expect a higher price variation to promote a more stable trade relation. The GDP per capita is of special interest as the increase in seafood consumption is considered to be correlated with income increases all over the world (FAO, 2022). The firm-specific variables that are used in the model are the ratio of the number of trade transactions<sup>5</sup> (or shipments) at the end of the trade spell to the first year of a trade spell; the trade level at the last year of the trade spell; a dummy block for type exporters (wholesaler, processor or primary

<sup>3</sup>ERS International Macroeconomic Data Set: <https://www.ers.usda.gov/data-products/international-macroeconomic-dataset/>

<sup>4</sup>World Bank Open Data: <https://data.worldbank.org/indicator>

<sup>5</sup>Number of trade transaction refers to number of times that two partners trade with each other and used in trade literature: <https://www.census.gov/programs-surveys/ces/data/restricted-use-data/longitudinal-firm-trade-transaction-database.html>

producer); the type of transport from Norwegian borders (only rail, only road, only ship, only flight, a mix); and a fix effect for the 2005 year to account for the right censoring of data.

## 6 | EMPIRICAL RESULTS AND DISCUSSION

The results presented here are those with a maximum explanatory power that reduce the identification problem as much as possible. Table 2 presents the distribution of active spells across Norway's salmon trade relations. The average length of each spell is 2.39 years in this case. It shows the short-time relation between exporting and importing firms within the salmon trade. The maximum number of spells in 14 years of the available data is five. 12% of the trade cases have more than one spell. We considered all levels of trade in this analysis, and the trade duration analysis have left and right censoring issues in the dataset. There are observations that we could not recognize at the beginning of the trade time and are at the primary stages in sample; if we eliminate those observations, many observations will drop off. Therefore, we kept them and a dummy was added to COX PH to control for those observations that show trade in 2005. The right censoring was controlled throughout the analysis.

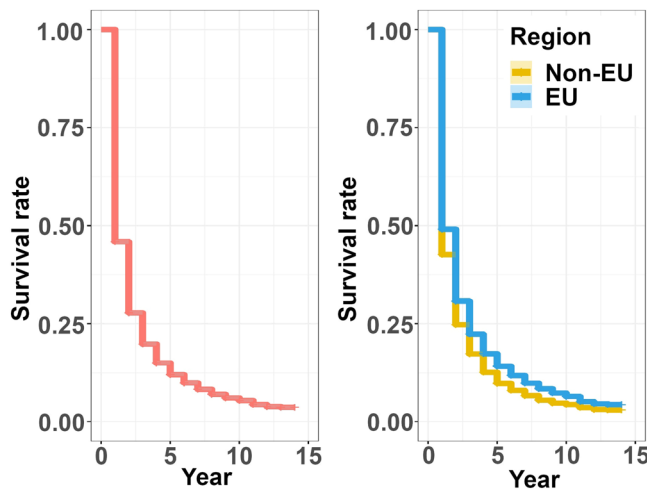
### 6.1 | Kaplan–Meier results

The information in panel B of Table 2 are the results of the Kaplan–Meier estimation, which is explained in the methodology section. By using these results and a further expansion of them, we can establish the survival function

**TABLE 2** Distribution of active spells across the Norwegian salmon trade relationship, 2005–2018, with the survival rate estimation for the different spell length.

Panel A: Total no. of spells in a relationship between importer and exporter firms			Panel B: Observed spell length in a relationship between importer and exporter firms			
No. of spells in a relationships	No. of relationships	Frequency	Spell length (year)	No. of relationships	No. of events	Survival rate
1	29,268	87.82%	1	33,326	18,038	45.87%
2	3404	10.21%	2	12,672	4,996	27.79%
3	569	1.71%	3	6547	1,878	19.82%
4	82	0.25%	4	3901	947	15.01%
5	3	0.01%	5	2574	511	12.03%
Total	33,326	100%	6	1702	295	9.94%
			7	1230	203	8.30%
			8	929	142	7.03%
			9	673	92	6.07%
			10	489	53	5.41%
			11	367	72	4.35%
			12	243	27	3.87%
			13	177	9	3.67%
			14	130	0	3.67%

Source: Study results.



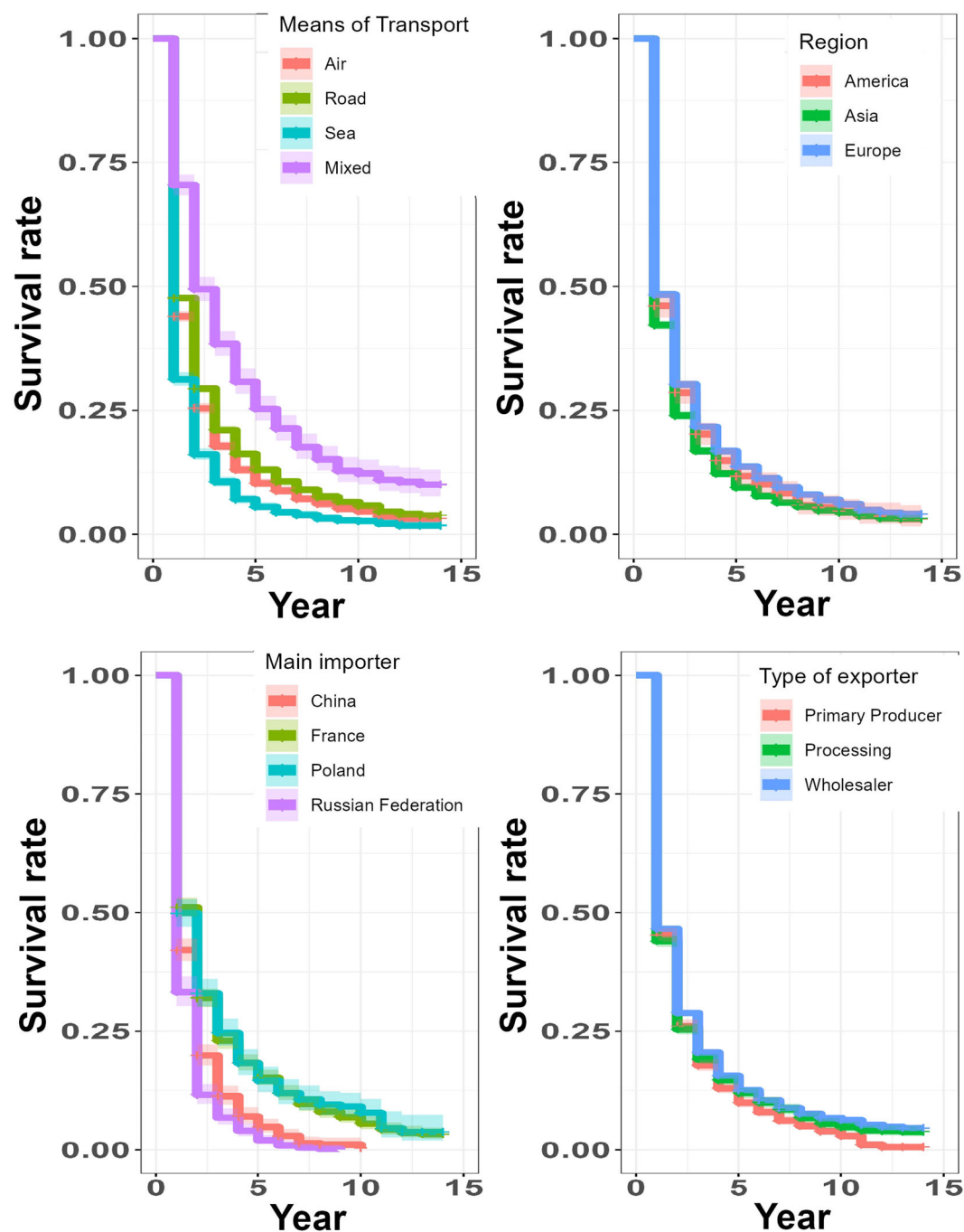
**FIGURE 3** Kaplan-Meier survival function, all firms (left) and EU/non-EU separately (right). Source: Study results

(see Figures 3 and 4). The survival function shows how the variables of the study, which is the time until the end of the trade, behave and how fast the trade relations die out. Panel B of Table 2 and Figure 3 show that only 27% of the trade relations continued after the second year and more than 70% of the trade relations are already dead after 2 years. These graphs in Figures 3 and 4 show how some explanatory variables influence the survival probability.

In all of these figures, the y-axis refers to the survival rate of the trade relationship and the x-axis is the years of interaction. Figure 3 shows that the survival rate for the long-term trade relation is low and the difference between EU and non-EU trade relations in the long run is not vastly different. Figure 4 shows that there is not a huge difference between continents considering the length of trade relationship. However, those partners who have diversified means of transport probably stay in a trade relationship for a long time. Figure 4 shows that after the third year, the probability of trade survival for primary producers as the exporters is lower compared with wholesaler and processors. The probability of a long-term trade survival between Norwegian exporters and Polish and French partners, which is the main hub for the secondary processing of salmon, is almost higher. Considering the observations by Gullstrand and Persson (2015) on core and periphery markets, it seems that the major importers who are doing the secondary processing are the core market with a higher survival rate for Norwegian salmon exports. The trade duration between Norway and Russia is low due to having included the 2014 ban in the sample; the trade duration with China is not an old trend and could change in the future.

## 6.2 | COX PH and frailty models

As it is explained in the methodology, COX PH, weighted COX PH, and frailty models (COX PH with the random effect) were estimated. Considering the results of the proportionality test (see section 3.1.4) and software limits, we estimated two groups of models in Tables 3 and 4. Group one consists of simple and weighted COX PH models and group two consists of frailty models. Three blocks of restricted base models, a restricted base model with the 2005 dummy and extended models were estimated. These three blocks of models in the frailty category were estimated with two random effects: one frailty model with the importing country and the exporting regions' random effects and the other frailty model with the importing country and the exporting firms' random effects. It must be added that the comparison between the frailty models were estimated via the "coxme" package in R, which was only possible by



**FIGURE 4** Kaplan-Meier survival function separated by means of transport (top left), continents (top right) by main importers (bottom left) and type of exporter (bottom right). Source: Study results

comparing the estimated maximum log-likelihood of the models. This reason is due to the impossibility of testing  $H_0 : \sigma = 0$  as the ordinary asymptotic theory does not hold for parameter values at the boundary parameter space, which was the case here (Broström, 2022). Nevertheless, the model selection criteria showed that the exporting firms' specific frailty effect has a higher explanatory power compared with the exporting region frailty effect.

TABLE 3 COX PH and weighted COX PH estimations for salmon firm-to-firm trade duration between Norway and partners.

Variables	Restricted basic models		Basic models with 2005 dummy		Extended models	
	Normal	Weighted	Normal	Weighted	Normal	Weighted
<i>Proportional</i>						
GDP per Capita (log of USD)	-0.087 (0.007)***	-0.058 (0.005)***	-0.087 (0.007)***	-0.057 (0.005)***	-0.049 (0.007)***	-0.037 (0.005)***
Exporter processing (dummy)	-0.031 (0.021)	0.002 (0.015)	-0.030 (0.021)	0.004 (0.015)	0.140 (0.022)***	0.095 (0.015)***
Exporter wholesaler (dummy)	-0.088 (0.018)***	-0.043 (0.013)***	-0.088 (0.018)***	-0.042 (0.013)***	-0.024 (0.018)	-0.003 (0.012)
EU dummy (1 EU, 0 non EU)	-0.069 (0.020)***	-0.050 (0.014)***	-0.069 (0.020)***	-0.050 (0.014)***	-0.087 (0.020)***	-0.059 (0.013)***
Rail transport_2 (dummy)	0.018 (1.000)	-0.376 (0.017)***	0.018 (1.000)	-0.378 (0.017)***	-0.224 (1.000)	-0.549 (0.016)***
Road transport_3 (dummy)	0.010 (0.021)	0.002 (0.015)	0.010 (0.021)	0.003 (0.015)	0.011 (0.021)	0.012 (0.014)
Ship transport_4 (dummy)	0.256 (0.020)***	0.182 (0.013)***	0.256 (0.020)***	0.182 (0.013)***	0.137 (0.021)***	0.108 (0.013)***
Mix transport (dummy)	-0.570 (0.032)***	-0.527 (0.027)***	-0.570 (0.032)***	-0.527 (0.027)***	-0.460 (0.032)***	-0.420 (0.027)***
<i>Nonproportional</i>						
Firstyear_2005 (dummy)			-0.004 (0.018)	-0.019 (0.013)	-0.389 (0.019)***	-0.299 (0.012)***
Ratio of number of transactions in last year to 1st year					-0.039 (0.002)***	-0.062 (0.004)***
Trade weight in last year (tons)					-0.001 (0.000)***	-0.001 (0.000)***
FOB price per unit (NOK/KG)					-0.007 (0.000)***	-0.004 (0.000)***
SD of salmon price in Norway					-0.193 (0.004)***	-0.127 (0.003)***
No of observations: 33,236						
No. of events: 27,186						
Log null: -26.0911						
Loglike	-260,331		-259,026		-25,7201	
R2/concordance (max is 1)	0.586 (0.003)		0.586 (0.003)		0.724 (0.002)	
LR test	1161***		1161***		7421***	
Wald test	1140***	9738***	1140***	9734.4***	6542***	22,031***
Score(Logrank) testfff	1161***		1161***		6146***	

Note: Significance codes: \*\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$ ,  $p < 0.1$ , standard error in parenthesis.

TABLE 4 Frailty model estimation for salmon firm-to-firm trade duration between Norway and partners.

Variables	Restricted basic models		Basic models with 2005 dummy		Extended models	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
<i>Proportional</i>						
GDP per Capita (log of USD)	−2.853 (0.048)***	−2.690 (0.053)***	−3.218 (0.059)***	−3.009 (0.055)***	NA	NA
Exporter processing (dummy)	0.203 (0.027)***	0.236 (0.111)*	0.220 (0.027)***	0.298 (0.114)***	0.311(0.027)***	0.328(0.110)***
Exporter wholesaler (dummy)	0.101 (0.022)***	0.239 (0.109)*	0.102 (0.022)***	0.280 (0.112)*	0.132(0.021)***	0.290(0.108)***
EU dummy (1 EU, 0 non EU)	NA	NA	NA	NA	NA	NA
Rail transport (dummy)	−0.484 (1.006)	−0.621 (1.007)	−0.510 (1.005)	−0.614 (1.006)	−0.626 (1.007)	−0.686(1.008)
Road transport (dummy)	−0.008 (0.030)	−0.001 (0.032)	−0.019 (0.030)	−0.003 (0.032)	−0.024 (0.030)	−0.010(0.032)
Ship transport (dummy)	0.141 (0.023)***	0.120 (0.024)***	0.119 (0.023)***	0.092 (0.024)***	0.073 (0.023)***	0.048(0.024)*
Mix transport (dummy)	−0.511 (0.033)***	−0.516 (0.034)***	−0.508 (0.033)***	−0.510 (0.034)***	−0.449 (0.033)***	−0.457(0.034)***
<i>Nonproportional</i>						
Firstyear_2005 (dummy)			−0.330 (0.019)***	−0.389 (0.021)***	−0.492 (0.019)***	−0.546 (0.021)***
Ratio of number of transactions in last year to 1st year					−0.038 (0.002)***	−0.037 (0.002)***
Trade weight in last year (tons)					−0.001 (0.000)***	−0.001 (0.000)***
FOB price per unit (NOK/KG)					−0.006 (0.000)***	−0.007 (0.000)***
SD of salmon price in Norway					−0.155 (0.004)***	−0.148 (0.004)***

<i>RE (sd)</i>						
RE: Importing country (sd)	4.03	3.83	4.58	4.3	2.57	2.41
RE: Exporting region (sd)	0.29		0.29		0.26	
RE: Exporting firm (sd)		0.39		0.41		0.38

(Continues)



TABLE 4 (Continued)

Variables	Restricted basic models		Basic models with 2005 dummy		Extended models	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
No of observations: 33,236						
No of events: 27,186						
Criterion						
Log null: -26,0911						
loglike	-259,026	-257,702	-258,692	-258,204	-256,632	-256,251
Integrated Likelihood ( $\chi^2$ )	3770	5039	4438	5416	8559	9321
AIC	3752	5019	4416	5394	8529	9291
BIC	3678	4937	4326	5303	8405	9168

Note: Significance codes: \*\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$ ,  $p > 0.1$ , standard error in parenthesis ().

The results are presented in Tables 3 and 4. It must be mentioned that if part of the block of the dummies were not violating the proportionality assumption, we considered that in the restricted base models. Furthermore, the frailty model with the importing firms' specific random effect did not converge. Therefore, we considered the frailty effect for exporters or exporting regions as a cluster of exporters and importing countries as a cluster of importers. In these models, the factors that affect the hazard of the trade relations are tested. If we consider the end of relation as one (1) and the continuation of this relation as zero (0), the positive coefficient shows how the exogenous factor increases the probability of hazard and the negative coefficient shows how the exogenous factor decreases the probability of hazard. Having this analogy in mind, the coefficients of COX PH model are interpretable. The basic models with the 2005 dummy were selected as the proportionality test was weakly significant for the 2005 dummy. The results of the estimation between the basic COX PH, the basic COX PH with the 2005 dummy and the extended COX PH (simple and weighted) were similar in the main parts. However, some minor differences between the different models in Table 3 and some major differences between Tables 3 and 4 were recognizable. Most of the models show the probability of longer trade relations with higher-income countries. However, the GDP per capita was dropped from the extended model with two random effects. It seems that the frailty model, which suffers from nonproportionality in some covariates, is not able to explain the effect of income growth. However, consistent results could be recognized in all other models.<sup>6</sup> Considering the sign and significance level of the four dummy variables for the five types of transport (air, rail, road, ship, and diverse), we can see that those partners who use diverse means of transport have a higher chance of longer trade relations and this finding was robust among all models. With contrasting results, the weighted COX PH models show that rail transport also increases the length of trade relations. The results of all models show that ship transport has a negative effect on trade duration. This can be explained by considering the structure of the transport of exports from Norway. For instance, Hanssen et al. (2014) have shown that in 2013, the transportation of exports of salmon and trout from different borders of Norway was divided into 81.1% for road and rail transport, 10.8% for flights, and 8.1% for boats and ferries. The role of naval transport was even reduced from 12.5% in 2007. We can argue that a longer trade duration is expected from nonnaval transport or utilizing a diverse means of transport. The two dummy variables on the type of exporters (primary producers, processors, and wholesalers) in different estimated models of Tables 3 and 4 show contrasting different levels of significance, signs, and magnitudes. In Table 3 (simple and weighted models), the probability of longer trade with wholesalers is higher and the processors' dummy in most of the models is insignificant except for the extended models. In the extended model, trade with processors should come to an end soon. In the frailty models (Table 4), both processors and wholesalers have a positive sign, which means the hazard rate is higher. However, the magnitudes of the coefficients show that we have a lower hazard rate for trade with wholesalers. The covariates, which violates the proportionality assumptions, also has an interesting effect on the model. By looking to the results in the extended block of models, we can recognize that the 2005 dummy variable for controlling the left censoring issue is significant and negative. It shows we have a year fix effect and periodical differences for some covariates. In the round of model selection, the time fix effect is used as a group of 13 dummies for 14 years of data. The block of dummies didn't improve the model but the 2005 dummy affected the models. The significance of the 2005 dummy variable had a negative sign in some models, showing that those partners that have older relations before 2005 have the probability of a longer trade duration. All extended models in Tables 3 and 4 show that the higher ratio of the number of trade transactions (or shipments) at the end of the trade spell to the first year of the trade spell can increase the possibility of longer-term relations. This can be considered as a higher extensive margin of trade, which in the case of salmon can increase the trade duration. A higher volume of trade is also a factor that encourages longer relations. However, the level of exports at the initial year of the trade spell did not affect the model, showing that the size of the trade at the last year of spell was more affective and the intensive margin was only effective at the last year of the spell. A higher value of supply, which

<sup>6</sup>We were technically limited to having a frailty model with some treatment to nonproportional covariates, which is the reason for presenting all the models.

was reflected by the FOB value per unit, increases the possibility of trade survival. A higher variation of price over a year in Norway causes longer relations. It could be that the decisions about imports are made by observing the price changes in Norway. These are the results of all models in the extended block.

The dummy variables for the EU fix factor was significant in all models in Table 3 but not in the frailty models in Table 4. It seems that the EU countries' effect is captured by the country-level frailty effect. The negative sign and magnitude show that the EU importers have slightly lower hazard rates compared with other countries. We already saw a slightly higher survival rate of spells for EU partners by the Kaplan–Meier estimation. We were expecting a higher survival rate for the EU generally. As was explained in the introduction, we were expecting more stable and long-term relations between partners as salmon is a perishable product, especially for markets nearer to Norway such as the EU, which is the major geographically close importing hub for salmon.

The exchange rate was not significant and was not considered for the final models. The other noneffective covariates are distance, exporting firms' employees, the indicator of multiple spells, and other covariates explained in the data section. Generally speaking, the random effect model did not improve the model dramatically. Finally, the proportionality assumption and availability of unobserved heterogeneity make it difficult to decide on a model that has the best presentation of data. However, having fewer statistical technical problems, the restricted basic models with the firm frailty effect can be considered the best model. Nevertheless, all extended models provide a picture on the direction and magnitude of the hazard ratio for covariates that do not hold the proportionality assumption.

### 6.3 | Discussion

We expected a longer relation between trade partners for a perishable commodity such as salmon. However, the results show that the survival rate between the Norwegian salmon exporters and the major global importers is rather low. On average, the trade relationship between firms is 2.39 years for the period of 2005–2018. This is even lower than findings of Straume (2017) for firm-country relations, which was 4 years. In particular, for most of the firms, the likelihood that the trade of salmon survives after 2 years is about 28%, and after 5 years about 12%. This rate is slightly different between EU and non-EU countries after 5 years, which largely vanishes in the long run. Most trade relations die out after 2–3 years on average, independent of the importers' origin (EU/non-EU). As the trade partners change fast, at the same time the overall trade volume increases, indicating that entry and exit in trade partnerships are not very costly. These are further insights into the trade duration puzzles as we have explained in the introduction. We were expecting long-lived trade relations between firms due to the perishable nature of salmon (see Peterson et al., 2018). Furthermore, at the same time, two variables have significant reducing effects on the hazard ratio: the effect of the size of trade (intensive margin) during the last year of a trade spell and the ratio of the number of transactions (shipments) during the last year of a trade spell to the first year (as a proxy of extensive margin). This shows that, despite the short-lived relations of trade spells on average, the partners trading larger amounts of salmon and in more shipments are more often expected to stay longer in a trade partnership that's in line with HFTM. We can conclude that despite having mainly short-lived trade relations, more intensive and extensive margins can still cause lower hazard and longer trade durations. Nevertheless, the long-run trade relationships are of lower importance in the whole sample. By decomposing the results further and comparing the Kaplan–Meier for major processing hubs, we can conclude that the longest and highest survival rate is for Poland and France (Figure 4). This higher survival rate for processing hubs compared with all other partners show that, similar to Gullstrand and Persson (2015), we can have core and periphery markets for salmon and processing hubs are the core market with longer trade duration relations. Decomposing the results by type of exporting firm, after 3 years of trade, the rate of trade survival is higher for salmon wholesale and processing firms compared with the primary producers. This difference widens slightly further as the duration of continuous trade increases. Different econometric models were not very informative in the case of the type of exporting firm; however, they show the

probability of lower hazard for trade with wholesalers, which is similar to the results of the Kaplan–Meier estimator. The positive effect of the higher value of exports on the reduction of the hazard ratio shows that the exporters are probably more interested in stable partners when prices are higher or higher-valued commodities are traded. Furthermore, as the international prices become more volatile, the incentive of having longer trade relationship increases. This shows that stable partners are of more importance in turbulent times and markets. Norway salmon exports enjoy the natural monopoly of salmon production, and entries and exits in this market are fast, which can only be changed by the availability of more long-term contracts between partners or more actors on the supply side. If trade to the regions with other competitors such as the US increases, we could expect other patterns of trade durations for these markets. Norway was excluded from the US market by higher tariffs for many years (Reuters, 2012) until 2012 and Chile was playing a more important role in those US markets (Xie & Zhang, 2014). The pattern of the salmon trade between Chile, Norway, and the US would certainly be an interesting area of research if more data was available. Similar to Straume et al. (2020) and Asche et al. (2021), who recognized different patterns in the intensity of the salmon trade, we also found different patterns in the duration model at the firm level. As the distance was not significant and did not affect the hazard model, one divergence from the trade literature appeared. The anonymity of the exporters did not allow us to test more firm-level factors on trade duration. We expected significant reducing effects on the hazard ratio due to economies of scale, which could have been presented by employees of the exporting firms. However, this was not significant and has no effect on the hazard model. If more firm-level specific characteristics, such as current revenue and costs could be acquired, the HFTM could be tested better. Finally, we can predict that similar patterns would be found for Chile as the main other salmon exporter and for any other perishable food products that are provided by few suppliers around the world. The results of this study can surely not be generalized for all trade patterns as found already by Asche et al. (2021), although they can be a way forward for exceptions. Additionally, these findings hint that trade duration puzzles are even available for perishable commodities.

**Study limitations:** the findings of this study have to be seen in light of some limitations. The underlying Cox proportional hazard model (or COX PH) in this study and the covariates assigned to it for the specification of the model were decided upon based on the available trade duration literature at the country-commodity or firm-commodity levels. Additionally, we were limited from using the valuable control variables that were included in the observational data provided by SSB Norway (firm-level trade transaction data) due to privacy and anonymity restrictions. This limited number of control variables caused some serious issues in the identification strategy of this paper.<sup>7</sup> The problems are considered serious because the exogeneity of some of the covariates in this study are questionable. For instance, the type of exporters (primary producers/processors/wholesalers) can have confounding effects on the size of exports, which affects the hazard ratio. Considering the nature of covariates in trade studies similar to other nonrandom observational studies, there could also be other observed or unobserved confounding effects in the model. If we had had further information on the characteristics of the exporters, we could have further controlled the variables in the model and established sound instrumental variables, for instance, to deal with confounders (Hünemund & Bareinboim, 2023; Imbens, 2014) and show a sound causal effect in the model. However, we noticed that the issue of confounders and endogeneity is mainly neglected or ignored in trade duration studies from the literature available to date for the 2006–2023 period. This could be due to model restrictions, for instance, proportionality assumptions or the nonlinearity structure of the semiparametric hazard models. Additionally, if we had further control variables, we could employ methods such as propensity score matching (Austin, 2011) or the control function method (Glewwe & Todd, 2022) to deal with endogeneity and confounding effects of observational studies, like other trade studies using country level or firm level trade transactions data. Another limiting factor that we were faced with and could not control for was possible heteroscedasticity in the model due to the availability of clusters of importers in the data. We failed to test and

<sup>7</sup>Thanks to one of the anonymous reviewers of this paper, we became aware of the identification problems and the econometric challenges available in trade duration studies and this current research, and thus we address them here.

correct this issue by holding the restrictive assumption of proportionality in the nonlinear semiparametric COX PH model. We have employed the frailty models to deal with unobserved heterogeneity, but other possible clusters in the data could not be dealt with. The issue of the possible availability of heteroscedasticity due to clusters was also met with software limitations when it came to testing and re-estimating the model. Nevertheless, we noticed that the testing for heteroscedasticity and correcting for that is another missing area in the available literature on trade duration from 2006 to 2023. To conclude, the causal effect of our hazard model is questionable and the interpretation of the estimations of the COX PH model should be treated cautiously and more as correlation than causality. These problems will be tackled in our future research in this field.

## 7 | CONCLUSION

Any decision about entering a trade market can be made easier by knowing the persistency of trade between partners and there are also commonalities and differences between markets. In this study, we've used firm-level trade transaction data to study the trade duration for Norwegian salmon for the 2005–2018 period. We have used a Kaplan–Meier survival model, Cox proportional hazard model, and frailty models, with different specifications having been defined for each model. Generally speaking, we found a low-level survival rate for the Norwegian salmon trade at the firm level. In this study, we have seen a different structure of trade persistency. Similarities and differences have been recognized between exporters, means of transport, level of quantity, and continents. In the Kaplan–Meier survival model we could see a slightly higher survival rate of trade relations between Norway and the EU. Additionally, we see that a higher value of trade has positively affected the trade duration. This is also the case for annual price volatility, and we have seen that a higher standard deviation of annual prices has positively affected the trade duration. The GDP per capita also positively affects the trade duration in all models: The richer the importer, the higher the probability of trade duration. Moreover, the higher the number of transactions in the last year of trade spell compared with the first year, the higher the probability of a longer trade duration. Norwegian salmon production and exports are also free from competitors in major demand markets.

We can conclude that Norwegian salmon exports enjoy the natural monopoly of salmon production, and this does not show a largely different trade persistency with different markets. With the highest processing intensity of imported salmon, Poland and France are the core importing markets with a higher survival rate and the other markets are periphery. However, if trade to the regions with other competitors such as the US increases, we could expect other patterns of trade duration for these markets. Norway has been excluded from the US market for many years and Chile plays a more important role in those markets at the moment.

This research can be expanded by including new dimensions. The regional differences between exporters in Norway that we found in frailty models is a sign that issues such as disease outbreak on salmon farms can be studied further in the next stages of duration analysis. Furthermore, we suggest applying spatial analysis in the duration model when regional differences are recognized. The anonymity of the data did not allow us to study the possible spatial effects with spatial econometrics and this could be studied in the future if the exact position of those producers, processors, or wholesalers can be defined. Furthermore, in this study, we have focused more on firms; however, for the next stages of research, the effects of the differences between fresh and frozen salmon and other seafood items and their duration could be differentiated between. Moreover, once the relevant data becomes available, the effects of the COVID-19 pandemic for the period from 2020 to 2021 on trade duration could be studied in the next stages of this research.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

## DATA AVAILABILITY STATEMENT

The firm-level data that support the findings of this study are available from the Statistics Norway or (SSB) and they can be accessed upon an official arrangement with SSB only by Norwegian organizations and entities.

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